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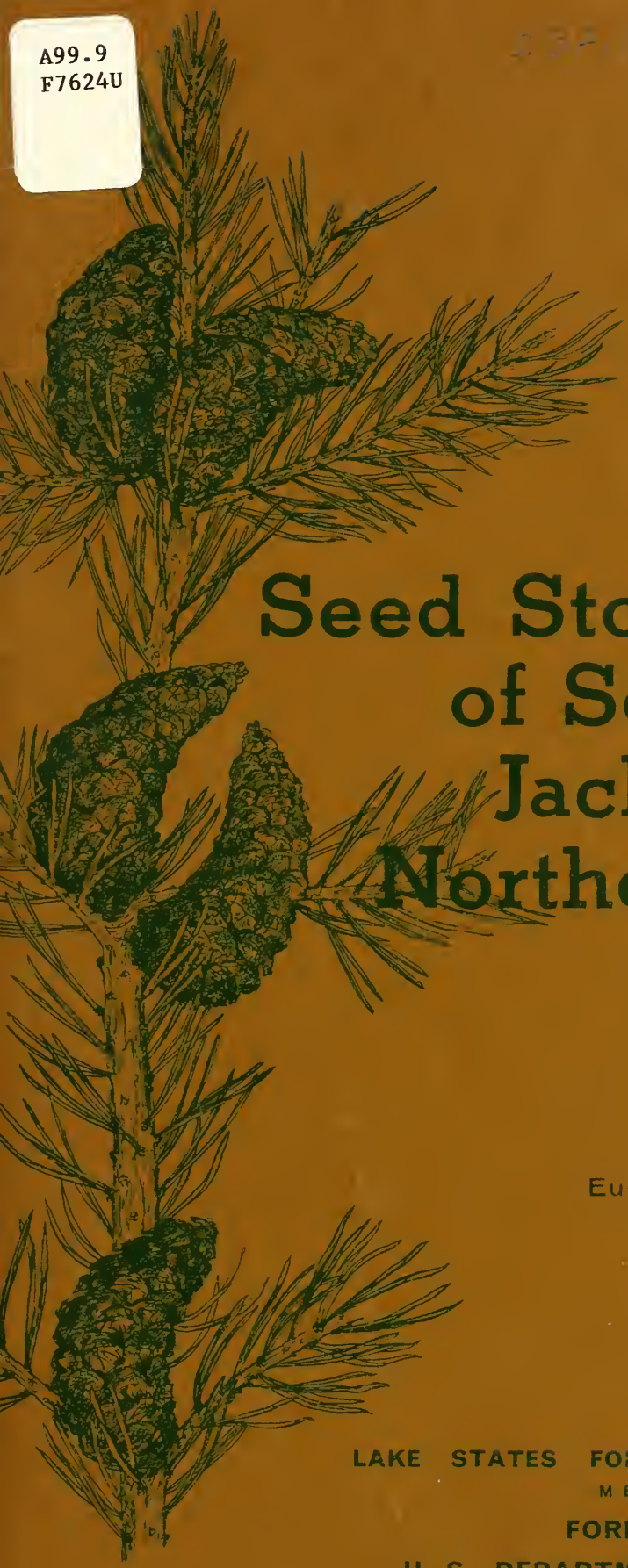

Seed Stored in Cones of Some Jack Pine Stands, Northern Minnesota

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CONTENTS

PLEASE NOTE

This is the first of a new series of reports to be issued by the Lake States Forest Experiment Station. These reports will be designated "U. S Forest Service Research Paper LS-—." They replace the Station Paper series, the last one of which was Station Paper 106.

Seed Stored in Cones of Some Jack Pine Stands, Northern Minnesota

by Eugene I. Roe[1]

Over much of the range of jack pine (*Pinus banksiana* Lamb.), its cones persist unopened on the trees for many years. Much of the seed thus accumulating on the trees remains viable and is available to regenerate the stands in the event of their destruction by fire. Since large areas of jack pine in Minnesota are being cut, a knowledge of the amount and quality of seed so stored is important for both natural regeneration and seed collection purposes. Considerable amounts of jack pine planting stock are produced, and there is a growing trend toward direct seeding. Sizable quantities of jack pine seed are needed for both operations.

This paper summarizes information collected on the amount and quality of seed retained in the cones of jack pine stands and trees, ranging from young plantations through mature stands to old veteran trees that are relicts in spruce-fir stands. These data are all from the northern and northeastern parts of the state where the cones are typically serotinous; no samples were obtained from central Minnesota where many of the cones open readily on the trees soon after ripening.

REVIEW OF GENERAL CONE AND SEED CHARACTERISTICS

Description and Time of Ripening

Jack pine cones occur usually in pairs toward the apex of the current season's growth. They ripen in September of the second year after flowering. Newly ripened cones are olive brown and 1 to 1½ inches long; their shape varies considerably from tree to tree. The cones may persist on the trees for 25 years or longer (Ellis 1911),[2] and they eventually become gray. This color appears on the side exposed to the weather about 2 years after ripening. Five-year-old cones are light to dark gray (Beaufait 1960a); old cones are dark gray and are often covered with lichens (Schantz-Hansen 1941).

In a given stand, some trees will have straight cones, others slightly curved cones, and still others strongly recurved cones (Schoenike et al. 1959). Shape is apparently associated with seed yield: In one study, straight cones averaged 46 seeds per cone, slightly curved ones 41 seeds, but strongly recurved cones only 21 seeds (Schantz-Hansen 1941).

In another study, cones with an average of 73 scales bore 50 seeds, of which 40 were filled; these were borne only by the upper 65 to 75 percent of the cone scales (Sterling 1903). This is confirmed by Aase (1915), who found the lower one-third or more of the cones to be infertile. Large cones are said to bear more seeds than small ones (Ellis 1911).

The moisture content of mature cones varies from 12 to 15 percent of oven-dry weight; that of the oldest cones runs about 11 percent (Beaufait 1960a, Schantz-Hansen 1941).

Cone Opening and Seed Dispersal

The dispersal of jack pine seed after it ripens depends on the opening characteristics of the cone. In the southern portions of its range, jack pine bears cones that open readily after ripening. Over most of the range, however, the cones are serotinous, sometimes remaining closed on the tree for as long as 25 years or more (Schantz-Hansen 1941).

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[2] *Names and dates in parentheses refer to Literature Cited, p. 13.*

In Minnesota, there is evidence that the cone type gradually changes from predominantly serotinous in the northeast[3] to nonserotinous in the central and southern parts of the state (Rudolph et al. 1957). Such a gradation is also suggested for the jack pine range in Michigan, Wisconsin, and the Northeast by observations made by the Station (Rudolf 1958) and by cone counts made of a jack pine seed source study at Cloquet (Schoenike et al. 1959). The dominance of nonserotinous cones in the southern part of the range is reflected in the abundant reproduction in and adjacent to jack pine stands. Where the cones are primarily serotinous, such reproduction is rare.

Although it was believed earlier (Schantz-Hansen 1941) that serotinous and nonserotinous cones were seldom found on the same tree, recent evidence indicates that trees bearing both types of cones occur rather frequently (Schoenike et al. 1959).

Seed dispersal from nonserotinous cones begins in September and may continue intermittently over several years (Rudolf 1958). Both types of cones open readily after a fire in jack pine stands; seed dispersal occurs usually within the next few days (Eyre and LeBarron 1944) but sometimes may be prolonged for several months (Beaufait 1960b). In some instances, serotinous cones have opened and shed their seed in midwinter after periods of extremely low temperatures (Eyre and LeBarron 1944).[4] The reason for this unusual circumstance is not known, but it does not seem to be due to excessive drying of the cones (Beaufait 1960a). Occasionally, cones that have released their seeds will close again during moist weather and, unless closely inspected, will appear to be unopened.

The scales of serotinous cones are sealed, at least in part, by a material that is soluble in both petroleum ether and a 1:2 mixture of alcohol and benzene (Cameron 1953).[5] It may thus be resinous or composed of waxes, fats, or wood gums. Although this substance has not been analyzed, it softens at about 116° F. and melts at 122° F. (Cameron 1953). Once it has been removed with a solvent, the cones will open readily at air temperature, the time required depending on their moisture content.[5] Whether nonserotinous cones have a sealing bond with a lower melting point has not been demonstrated.

The temperature at which serotinous cones will open on the trees in the absence of fire is not known. Presumably it is somewhere in the neighborhood of 122° F. This is, of course, well above the maximum air temperatures commonly experienced within the range of jack pine in Minnesota.

No definite information is available on the temperatures to which the cones are subjected when fire kills a stand. Judging from studies of slash fires in Michigan, these may vary from 600° F. at 17 feet above ground to about 400° F. at 25 feet and 200° at 50 feet (Beaufait 1960b, 1961). Cones will open in a muffle furnace in 80 seconds at 200° F. and in 10 seconds at 800° F. Ignition occurs only when the cones are exposed for 3 to 5 minutes at 700° F; at 900° F. they will ignite in 60 seconds. The seeds show appreciable injury only when the cones burn; then loss in viability is complete. Since the heat of surface fires and crown fires is not known to ignite the cones of standing trees and since very high temperatures in the crowns seem unlikely to last even as long as 3 minutes, it is understandable why fires in jack pine stands do not harm the seed (Beaufait 1960a).

Cone Production

Cone-bearing ordinarily does not begin until jack pine is 5 to 10 years old when open grown and 10 to 25 years when in closed stands (Ellis 1911, Sterrett 1920). Viable seed has been produced by trees as young as 5 years and mature cones (seed quality not reported) by 4-year-old trees (Chisman and Bramble 1951, Wackerman et al. 1929). Production is at its best between 40 and 90 years (Ellis 1911, Sterrett 1920) and declines thereafter. Good crops of cones are said to occur every 3 to 4 years (U.S. Forest Service 1948); others feel that there is no definite seed crop pattern (Ellis 1911).

Production per tree varies. Ellis (1911) reports that a mature jack pine 15 inches in diameter and 90 feet in height will produce annually 300 to

[3] *Even here there are some nonserotinous cones produced (Schoenike et al. 1959). Seedfall in a partially cut mature stand on the Superior National Forest averaged 10,000 seeds per acre per year for a 5-year period (Eyre and LeBarron 1944).*

[4] *Unpublished data on file at the Lake States Forest Experiment Station.*

[5] *Neumann, F. Philip. Scale movements of jack pine cones. Unpub. Master's thesis, Univ. Minn., 24 pp., illus. (Typescript.)*

500 cones bearing 10 to 30 seeds per cone. Sterrett (1920) cites even higher figures: 1,000 to 1,200 cones annually with an average of 30 seeds per cone or about ¼ pound of seed for well-developed, vigorous trees.

Once the flowers have been fertilized, cone production may be reduced by various agents. One of these is the oak-pine rust (*Cronartium quercuum*), which causes the production of smaller cones with a higher proportion of empty seeds (Weir 1915). Another is cone-destroying insects. As yet little attention has been paid to such insects (the only reference available is Sterling (1903) who found unidentified insects destroyed the seed in about 7 percent of the cones); but judging from their importance in other pines, they likely cause appreciable losses of jack pine seed. After the cones are mature, many are cut off and opened for their seeds by red squirrels (*Tamiasciurus hudsonicus*) (Cheyney 1929, U.S. Forest Service 1941). In cutting off the paired cones, these animals often strip off considerable bark. This injury usually kills that part of the branchlet above the cones and thus indirectly reduces cone yields. Red squirrels will also cut off many branches bearing 1-year-old conelets (Cheyney 1929).

Germination and Retention of Viability

Jack pine seed ordinarily is not dormant and will germinate readily and completely in petri dishes (temperature 75° F.) in 4 to 11 days. Germination of seed covered with sand in flats requires several more days. Under natural conditions, seed germinates rapidly when moisture is favorable and the 10-day mean maximum air temperature exceeds 64° F. (U.S. Forest Service 1939).

The seed is relatively small; when dewinged and cleaned commercially, it averages 130,600 per pound (U.S. Forest Service 1948). Fresh hand-cleaned seed shows high germination, 90 percent or more.[6] Viability of seed stored in serotinous cones decreases with age, but the loss in germination capacity does not appear to be of much significance until the cones are 3 to 6 years old (Eyre and LeBarron 1944, Schantz-Hansen 1941). Seed from cones that are covered with lichens (and presumably 20 or more years old) may average as high as 50 percent in germination (Schantz-Hansen 1941). One report indicates 82 percent viability for seed from 16-year-old cones.[7] A somewhat better measure of the retention of viability would, of course, be the real germination which, based on filled seeds alone, compensates for fluctuations in the number of empty seeds. Nevertheless, these values do show that a sizable proportion of the seed in serotinous cones remains viable for a long period.

Seed Yield

Only a few data have been collected on the amount of seed available in the cones of jack pine stands. The yield from 1 acre of mature trees 60 to 65 years old on the Chippewa National Forest (all cones collected) agrees quite closely with that from a similar stand on the Superior National Forest: 38.5 vs. 31.4 bushels of cones and 12.9 vs. 13.5 pounds of seed per acre. Of these yields, over half of the approximately 2,000,000 seeds per acre came from cones over 4 years old (Eyre and LeBarron 1944). Germination ranged from 30 to 62 percent for seeds from the oldest cones to 77 to 84 percent for those from 2-year-old cones (Eyre and LeBarron 1944, Rudolf and Ralston 1953).

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[6] *Commercial lots usually run much lower; this is presumably because of injury to the soft seed during the dewinging process.*

[7] *Shen, H. L. Viability of the seed of jack pine from cones retained in the trees for various periods of time. Unpub. thesis, Univ. Minn. 1936.*

PRESENT STUDY

Since the early 1940's thousands of acres of overmature jack pine have been cut in northern Minnesota. The regeneration of such stands has, therefore, become of great importance. Reports from the Superior National Forest in the late thirties and early forties indicated that cone production had averaged only about 5 percent of normal.[8] Such reports suggest that the data reported by Eyre and LeBarron (1944) on the stored seed in mature jack pine in the mid-thirties may no longer be valid. Accordingly, cone production and yield data were obtained from two 70- to 80-year-old stands in the Superior. Later, smaller amounts of data were also obtained both from well-stocked younger stands (plantations on the Superior and 40-year-old timber on the Chippewa) and old, overmature trees (130, 186, and 196 years old) on the Superior.

Essentially, the procedure consisted of collecting representative samples of closed cones, extracting and cleaning their seed, and making germination tests to determine the number of viable seeds per cone. The cone quantity and quality data were then applied to stand tables to give the number of viable seeds per acre. However, some of the details varied from stand to stand.

In each of the four plantations sampled,[9] all of the cones were picked from seven trees, which were equally spaced diagonally across the plantation. For each plantation the average number of cones per tree multiplied by number of trees per acre gave cone production per acre. Likewise, seed production per acre was obtained by applying the seeds-per-cone averages (both total and viable) to the cone production per acre.

In the 40-year-old natural stand a complete cone count was made on 51 trees, covering the range in diameters present, which were cut in a National Forest thinning operation near Cass Lake. Of these trees, 33 were cut in a stand that had received three earlier thinnings; the remainder were taken from adjacent unthinned timber. All were measured for d.b.h. and total height and were classified as to crown position by the Lake States Tree Classification (Gevorkiantz et al. 1943). The average number of cones per tree was determined for each diameter class,[10] and these figures applied to local stand tables for thinned and unthinned stands to give the total production of cones per acre. The yield of seed, both total and viable, was then determined for average cones and these values used to convert cone production into seed per acre.

In the 70- to 80-year-old stands, complete counts were made of the closed cones on 44 trees, sampling the range in diameters present, which had been either cut in logging or recently blown down by wind. Data were recorded by cone-age groups and diameter classes to give the average yield for trees of different size. Four cone-age groups[11] were used for the 26 trees located in blowdown timber near Isabella. However, because of the extremely low temperatures when the counts were made, only two age groups (1942 to 1949 cones and older cones) were used for the 18 trees felled on a winter-logging job at Norway Lake about 18 miles northwest of the Isabella stands. In the final analysis, the data from the Isabella stand were also combined into these same two groups because the younger cones (those maturing between 1942 and 1949) showed close agreement not only in seeds per cone but also in their germination. Seed production per acre was obtained in the same manner as for the 40-year-old stand.

The cone samples from the overmature trees were also obtained from windthrown or logged trees, but because of the infrequency of these older age classes few trees could be included. Furthermore, only the younger cones were collected, since the objective in these cases was to determine to what age jack pine can produce viable seed.

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[8] *LeBarron, R. K. Report on "Reproduction and timber marking studies on Tomahawk-Kraft Paper Company sale area," Dec. 15, 1943. In files of Lake States Forest Experiment Station.*

[9] *Each was of Superior National Forest origin.*

[10] *These values were read from curves of cone production over d.b.h.*

[11] *These were: new cones (1949); cones 1 year old (1948); cones 2 to 7 years old (1942-1947); and old cones 8 to about 20 years old (before 1942). In the last group, cones that were somewhat soft, indicating possible opening and closing, were not included nor were cones with obvious worm holes.*

A brief description is needed on how seed counts and germination tests were made. After collection, a representative sample of the cones (or all cones where the number was limited) was drawn from each lot and counted. This was placed in a screen on a hot steam radiator. After the cones opened, they were shaken vigorously to remove the seeds. When this did not result in complete extraction, the cones were put momentarily in water and returned to the radiator for a second drying. If this procedure did not release all the seeds, another such cycle was used.

The seed was wetted and rubbed gently in a fine screen to loosen the wings. After the seed had dried, the wings and other light debris were removed by winnowing. Although this process got the seed quite clean, it did not, of course, remove many of the empty seeds. Consequently, the lots ran lower in soundness than the usual jack pine seed cleaned commercially in a fanning mill.

From each lot of seed thus obtained, a representative sample was drawn for germination tests. (If the yield was small, the entire yield was used.) Tests were run on moist filter paper in standard petri dishes kept, in the absence of a suitable germinator, at room temperature for 20 to 30 days. This somewhat crude arrangement proved adequate. Seeds remaining ungerminated at the close of the tests were cut to see if they were sound, spoiled, or blind. The following data were then calculated: actual germination (that based on all seeds sown), real germination (based on filled seeds only), viable seeds per cone (germinating plus sound seeds), and total seeds per cone (viable plus spoiled and blind seeds).

● CONE AND SEED PRODUCTION

In Plantations

Since the plantation cones contained many small seeds that were believed to be empty, each of the four seed lots after dewinging was separated into two fractions: (1) That passing through a 5/64-inch round hole grain screen, and (2) that retained by such a screen. As expected, the seed retained by the 5/64 screen was substantially heavier than that which passed through; it averaged 119,500 seeds per pound compared to 153,200 seeds for the smaller seed (table 1). Combining the two sizes gave 134,300 seeds per pound, indicating that the seed generally was of average size (Seed Manual average is 130,600) (U.S. Forest Serv. 1948).

Actual germination, considering that the seed was hand-cleaned, was good; it varied but little from plantation to plantation. And real germination, except for one sublot with 96 percent, was 99 and 100 percent. Since the seed was of remarkably uniform viability (table 1), it was pointless to segregate the two seed-size classes. They were, therefore, combined for the calculation of both seeds per cone and seeds per acre.

Except for the oldest plantation, the total number of seeds per cone and the viable seeds per cone showed little variation. The number of cones produced, however, was considerably more variable. As a result, there was a wide range in both total seed and viable seed production. But even the poorest yielder, the oldest plantation (with its fewer cones per tree and much fewer seeds per cone) had 332,000 viable seeds per acre or more than 2½ pounds of seed. And the best plantation had 5 pounds. These amounts would certainly be adequate for replacing such stands if they were destroyed by fire.

In 40-Year-Old Timber

In the 40-year-old timber, the thinned stand bore more than twice as many cones per acre as the unthinned stand and, while the former yielded fewer seeds per cone, a much higher percentage of them germinated. As a result, seed production in the thinned stand was over three times that of the unthinned timber (table 2 and fig. 1).

Cone production increased with diameter (table 2). Height also was related to production as will be seen in the following tabulation:

Height of trees	*No. of cones per tree*		*Basis, no. of trees*
	Average	*Range*	
37-44	14	0-32	14
45-50	76	0-308	16
51-56	118	8-352	20

TABLE 1. — *Amount and quality of seed in closed cones of well-stocked jack pine plantations Superior National Forest*

Total age (years)[1]	Size of seed	Clean seeds per pound	Germination		Seeds per cone		Basis cones[3]	Trees per acre	Cones per acre	Seeds per acre[4]	
			Actual	Real[2]	Viable	Total				Viable	Total
		Number	*Percent*	*Percent*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
9	Large	118,900	88	99	36.8	41.4	369	650	17,132	630,500	709,300
	Small	154,400	90	100							
10	Large	114,800	89	99	35.5	39.0	142	550	11,157	396,100	435,100
	Small	157,200	94	99							
11	Large	115,600	94	99	34.0	36.2	136	600	11,657	396,300	422,000
	Small	146,300	94	96							
13	Large	131,000	88	99	26.7	29.9	128	680	12,434	332,000	371,800
	Small	153,500	92	99							
ALL	Large	119,500	89	99							
	Small	153,200	92	99							
Weighted average or total		134,300	91	99	34.4	38.2	775	626	13,862	476,900	529,500

[1] Includes 2 years for age of planting stock.

[2] Based on filled seed only.

[3] Total production of 7 trees in each plantation except for the 9-year one; this was a much larger plantation and had 14 trees sampled.

[4] Production per tree times the number of cones per acre.

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FIGURE 1. — 40-year-old jack pine, Chippewa National Forest. This thrice-thinned stand bore over ¾ million viable seeds per acre (5.8 pounds) in its closed cones.

TABLE 2. — *Amount and quality of seed stored in cones of well stocked stands of 40-year-old jack pine, Cass Lake, Minn.*

D.B.H. (inches)	Unthinned stands			Thinned stands		
	No. of cones		No. of trees sampled	No. of cones		No. of trees sampled
	Per tree	Per acre		Per tree	Per acre	
4	0	0	0	25	2,250	5
5	23	1,932	2	42	3,864	4
6	53	4,346	5	55	4,785	7
7	69	4,347	2	77	8,239	7
8	82	2,460	4	118	5,310	7
9	92	184	3	192	3,840	3
10-11	103	103	2	192	576	0
Total		13,372	18		28,864	33
Viable seeds per cone			16.9			26.3
Viable seeds per acre			226,000			759,100
Total seeds per cone			33.0			28.9
Total seeds per acre			441,300			834,200

Crown position appears to affect cone production; the number of cones per tree tends to decrease as crown position becomes progressively less dominant:

Crown class:	*No. of cones per tree*	*Basis no. of trees*
Open grown	128	1
Head dominant	168	7
Strong dominant	64	15
Conditional dominant	81	14
Codominant	48	10
Intermediate	7	3
Suppressed	0	1

In 70- to 80-Year-Old Stands

In the 70- to 80-year-old stands, cone production in the Isabella trees averaged higher than that at Norway Lake. However, since there was no stand-table information available for either area, their data were combined. The average yield per tree (fig. 2) was then applied to the stand table used for medium-stocked jack pine poles by the Superior National Forest to give the cone yield per acre (table 3).

For both young and old cones, the yield per tree increased markedly with diameter, the largest trees being the best producers. The average tree bore about as many old cones as young ones. As in the 40-year-old stands, total yield per tree tended to increase as crown position became more and more favorable. This conclusion, however, is based on only 14 trees.

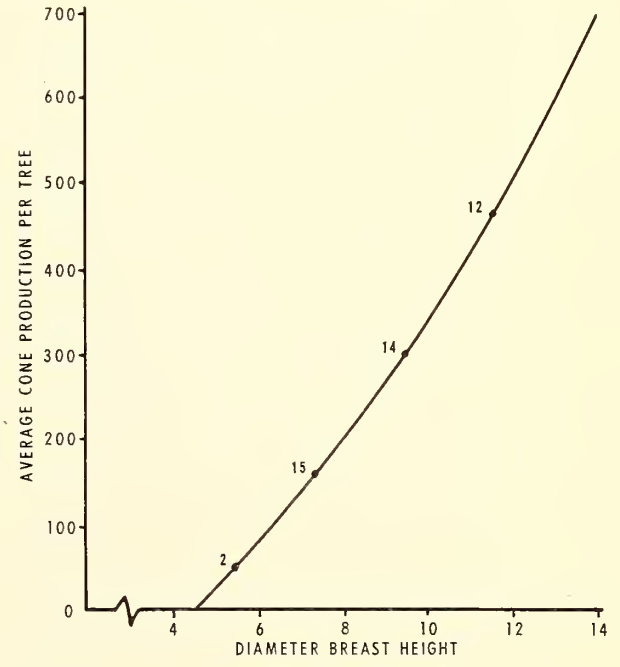

FIGURE 2. — Average yield of cones per tree in relation to diameter; 70- to 80-year-old jack pine, medium stocking, Superior National Forest. The encircled numbers are the numbers of sample trees in each diameter class.

TABLE 3. — *Average and per-acre yields of cones by trees of different diameters, 70- to 80-year-old jack pine of medium stocking, Superior National Forest*

D.B.H. class (Inches)	Yield per tree: No. of —				No. of trees per acre[1]	Yield per acre: No. of —		
	Young cones ripening 1942-1949	Old cones ripening before 1942	All cones	Basis, no. of trees		Young cones ripening 1942-1949	Old cones ripening before 1942	All cones
5-6	25	23	48	2	85.1	2,128	1,957	4,085
7-8	78	91	169	15	63.2	4,930	5,751	10,681
9-10	128	171	299	14	16.3	2,086	2,787	4,873
11-12	264	199	463	12	2.3	607	458	1,065
[2]13-14	355	296	651	1	0.7	249	207	456
Average all diameters	170	165	335					
Total				44	167.6	10,000	11,160	21,160
Average annual production						1,250	[3]797	

[1] From stand table for medium-stocked jack pine pole timber, Superior National Forest.

[2] The total yield of all cones was read from a curve as the one tree sampled bore 2,356 cones, almost 1,100 cones more than was borne by the next best tree. The ratio of young cones to old cones actually shown by this tree was then applied to the figure read from the curve.

[3] Based on an average age of 14 years.

Although Ahlgren (1959) found a total of 5,928 cones on one tree (size and age not given) on the Superior National Forest, the maximum number found on any of the 44 trees in this study was 2,356 (a 13-inch tree); the average yield, however, was only 335 cones. In contrast, the study made on the Superior in the mid-thirties showed 3,442 and 509 cones respectively.[12]

The largest annual crop found on any of the 44 trees was 198 cones, a 13-inch tree showing this production in 1949 and 167 cones in 1948. Although the maximum annual yield per tree in the earlier study was 363 cones (in 1935), the average for the 20 best trees in that same study was only 194.[12] It, therefore, seems that the average annual production of 300 to 1,200 cones per tree reported for mature jack pine by Ellis (1911) and Sterrett (1920) is much too high for this locality.

Cone production per acre averaged only 1,250 per year during 1942-49 and 798 per year prior to 1942 (table 3). This is in marked contrast to the average annual production of 6,059 cones per acre found in the earlier study on the Superior[13] and thus agrees with the observations made by LeBarron.[14] Although a considerable improvement in cone production had occurred since 1942, seed production was still well below that during the mid-thirties (Eyre and LeBarron 1944).

Cones produced before 1942 contained only half of the total seeds per acre yielded by those ripening since that time (table 4). This may have been the result of loss of some seed due either to opening and closing of the cones over the years or poorer cone and seed development. But, in spite of their relatively low number of seeds, these old cones were numerous enough to contribute about 30 percent of the total yield of viable seed.

Germination, considering that the empty seeds (a fourth of all seeds) were not removed by fanning as in commercial seed, was quite high. Although Schantz-Hansen (1941) found that the percentage of empty seeds was higher in the older cones, this was not true of these data. The lower germination shown by seed from the old cones was due mostly to the failure of 15 percent of the filled seeds to germinate; presumably these were already dead when the test began. This explains the much lower real germination shown by the seed from old cones.

[12] *Unpublished data, Lake States Forest Experiment Station.*

[13] *Unpublished data, Lake States Forest Experiment Station.*

[14] *See footnote 8, p. 4.*

TABLE 4. — *Quality and yield of seed stored in cones, 70- to 80-year-old jack pine of medium stocking, Superior National Forest*

Item	Cone origin		Total
	1942-1949	Prior to 1942	
Germination:			
Actual, percent	74	60	....
Real, percent[1]	97	80	....
Proportion of seeds:			
Spoiled, percent	2	15	....
Empty, percent	24	25	....
Basis, no. of cones	192	121	....
Seeds per cone:			
Viable, no.	26.9	10.0	....
Total, no.	36.4	16.8	....
Seeds per acre:			
Viable, no.	269,000	111,600	380,600
Total, no.	364,000	187,500	551,500

[1] Based on filled seed only.

Since the data given by Eyre and LeBarron (1944) on the stored seed supply on the trees of this age class when they were about 15 years younger are given in pounds of total seed, no direct comparison of the two periods can be made. However, translating the total yield of seed at 80 years into pounds by using the Seed Manual average of 130,600 seeds (U.S. Forest Serv. 1948) gives only 4.2 pounds (fig. 3) compared to the 13.5 pounds produced in 1935-36. And of these 4.2 pounds, only one-third came from cones produced before 1942. Further comparisons show that the viable seed supply of these mature stands was lower than that of most of the plantations and the thinned 40-year-old timber but was higher than the yield of the unmanaged 40-year stand.

Of Overmature Trees

The older trees had such limited bases that no attempt was made to determine the stored seed potential of such trees. Furthermore, the rather extensive 130-year age class on the Superior has only a light stocking of about 80 trees per acre; and the two older age classes sampled, 186 and 196 years, have such scattered trees that seed-per-acre figures would be rather meaningless. Of more importance is the knowledge whether such old, overmature jack pine can produce viable seed at their advanced age.

130-Year-Old Windfall. — In September 1949, fifteen gray cones that had been produced sometime during the period 1940 to 1947 were picked at random from the light crop borne by a 16-inch windfall near Forest Center, Minn. This tree, in the 130-year age class, had blown down in the severe windstorm of July 4. No 1948 cones and only two underdeveloped ones of the 1949 crop were found.

The cone sample, which comprised about one-third of the total crop, showed the following germination and seed yields:

Actual germination	82 percent
Real germination	91 percent
Empty seeds	11 percent
Spoiled seeds	7 percent
Viable seeds	22.6 per cone
Total seeds	28.0 per cone

F-415190

FIGURE 3. — 70-year-old jack pine, Superior National Forest. Stands such as this may contain over a half million viable seeds (4.2 pounds) per acre in their serotinous cones.

F-501990

FIGURE 4. — Decadent 186-year-old jack pine relict. This 16-inch tree had borne an average of 12 viable seeds per cone in 1949-1951; it was blown down in the late fall of 1951.

Yields of seed were, therefore, appreciably lower than those from cones of comparable age in the 70- to 80-year-old stands.

186-Year-old Relict. — A total of 61 cones maturing in 1949, 1950, and 1951 were picked at random from the top of a windthrown jack pine relict in a cutover balsam fir stand at Heart Lake on the Superior National Forest in late October 1951 (fig. 4). The tree was 16 inches d.b.h. and 186 years old. Since the cones varied considerably in length, they were separated into three size groups and their seeds were extracted and subsequently germinated.

The number of seeds per cone was even lower than the yield from those produced by the 130-year-old tree (table 5). Yield was definitely related to cone size. Although no cone-scale counts were made here, it seems likely, as has been found elsewhere,[15] that the largest cones had the greatest number of scales. This would explain their larger number of seeds. The proportion of empty seeds was also related to cone size, the number increasing as the cones became smaller.

196-Year-old Relicts. — The oldest jack pines known in Minnesota, and perhaps in the Lake States, are a few 196-year-old[16] trees on the Sand Lake Experimental Forest of the Kimberly-Clark Corporation. Judging from the down trees, they were the remnants of a jack pine stand that had been succeeded mostly by balsam fir. Representative 1- and 2-year-old unopened cones were obtained in October 1955 from the tops of two trees, one 16 and the other 20 inches d.b.h., which had been logged in June 1954 in connection with a balsam fir thinning study. Somewhat older cones were picked from a windfall that had been down for 3 or more years; this bore much smaller cones than the logged trees.

Since we know of no published records of the germination of jack pine seed from such old trees, the data are presented in table 6.

The number of seed per pound was determined for the seed from the 20-inch tree. However, since a third of these seeds were blind, this figure, 201,300 seeds per pound, does not give a reliable picture of the relative size of this old seed. The data do indicate that jack pine can still produce cones with an appreciable yield of viable seed at

[15] *Unpublished data, Lake States Forest Experiment Station.*

[16] *Age determined by ring count on a sound 2-foot stump.*

almost 200 years of age. Although no cone counts were made, the 16-inch tree produced cones until 2 years before cutting and the 20-inch tree had a heavy crop of cones of several years' origin. It, therefore, seems likely that both trees bore an appreciable amount of viable seed.

TABLE 5. — *Quality and yield of seed from cones produced in 1949-1951 by a 186-year-old jack pine, Superior National Forest*

Cone length (inches)		Germination		Empty seeds	Spoiled seeds	Seeds per cone		Basis, cones
Class[1]	Average	Actual	Real			Viable	Total	
		Percent	*Percent*	*Percent*	*Percent*	*Number*	*Number*	*Number*
1.31-1.70	1.44	71	97	27	2	19.3	27.0	15
1.10-1.30	1.20	64	99	35	1	11.2	17.5	28
0.91-1.09	1.05	49	98	50	1	6.7	13.8	18
ALL	1.22	63	98	36	1	11.9	18.8	61

[1] The longest cone was 1.70 inches; the shortest, 0.92.

TABLE 6. — *Quality and yield of seed from 1- and 2-year-old cones produced by three 196-year-old jack pines, Superior National Forest*

Tree condition	D.B.H.	Cone data					Germination		Empty seeds
		Origin	Avg. dry weight	Yield of seeds		Basis, cones	Actual	Real	
				Viable	Total				
	Inches	*Year*	*Gms.*	*Number*	*Number*	*Number*	*Percent*	*Percent*	*Percent*
Windfall	14	1949-51[1]	2.4	1.3	6.8	10	19	100	81
Cut but not used, decayed	16	1952[2] -	6.2	13.3	18.9	14	68	96	32
Cut and used	20	1953[3] -	6.1	15.1	25.0	12	66	97	33

[1] Estimated.

[2] No cones produced in 1953.

[3] Would have produced cones in 1954 and likely in 1955 as tree bore many partially developed cones and had also flowered heavily in 1954.

DORMANCY IN JACK PINE SEED

In a recent paper, Ahlgren (1959) suggests that fire may stimulate the germination of jack pine seed through the possible "action of heat in breaking the partial dormancy of seed frequently found in this species." This would seem to deserve detailed study, for in one test made of the seed from jack pine cones that had been partially charred in a slash fire the writer found that none of the seed would germinate even after alternations of favorable temperatures and chilling in a refrigerator. Yet the seed was still firm and apparently sound after about 100 days. This behavior suggests that the exposure of jack pine cones to temperatures high enough to scorch them, rather than favoring germination, may sometimes induce dormancy in this typically nondormant seed.

Such a possibility is also suggested by the results of seedling counts made 13 months after a mid-June crown fire in a 70-year-old stand of jack pine near Tofte, Minn. Although the cones had shed practically all their seeds within a week after the fire and just before a good rain, germination counts showed that 87 percent of the seedlings had originated the second spring. On the other hand, some spring fires hot enough to burn off the needles are followed by an abundance of first-year seedlings. Beaufait (1960a) obtained high germination, apparently without trouble, of seeds from young cones exposed to 900° F. for 30 seconds. However, when exposure was lengthened to 60 seconds at this temperature, the seed was all killed. Since the failure of the seed to germinate for 1 or 2 years after a fire has also been observed in Michigan (Beaufait 1962), further study of the possibility that extreme heat may induce dormancy in jack pine seed seems needed.

SUMMARY AND CONCLUSIONS

The number of closed cones borne by representative jack pine trees in stands of different ages in northern Minnesota was counted, and the number of cones per acre was estimated. Sample lots of cones were then opened by drying, and germination was tested. The average numbers of total seeds and viable seeds per cone were then applied to the cone counts to give total and viable seed per acre. Stored-seed estimates were thus made for four 9- to 13-year-old plantations, two 40-year-old stands, and two 70- to 80-year-old stands. In addition, tests of viability were run on seed from cones borne by 130-, 186-, and 196-year-old trees.

In both the 40-year-old and 70- to 80-year stands, the number of cones produced increased with d.b.h. The limited data available also indicated that within a given stand, cone production increased as crown position increased in dominance.

The amount of viable seed stored in the cones varied from 226,000 per acre in the 40-year unthinned stand to 759,000 for thinned timber of this age. Intermediate were 70- to 80-year jack pine with 381,000 and the plantations with 477,000 per acre. This is a range of 1.7 to 5.8 pounds of germinable seed, an amount which would be much more than ample under favorable conditions to regenerate these stands should they be destroyed by fire.

In the stands tested, the plantations bore appreciably fewer cones than any except the 40-year unmanaged timber. However, their greater yield of seed and its high germination made them second only to the thinned stand in viable seed supply. The greatest number of cones was borne by the 40-year-old thinning; this plus its sizable number of viable seeds per cone resulted in its superior yield.

The 70- to 80-year-old stands showed much lower cone and seed production than similar timber when it was 15 years younger. Total stored seed was less than one-third of the supply found in 1935, while that from the cones ripening before 1942 was about one-tenth as much. The improvement in cone production since 1942 suggests that at least part of the low cone yield of the late 30's was due to adverse climatic conditions, possibly drought.

Cones 8 or more years old in the 70- to 80-year-old stands yielded less than half the seeds per cone, both total and viable, produced by younger

cones. But since there were more older cones on the trees, they contributed almost a third of the viable seed. The lower yield of viable seeds in older cones was due in part to the fewer total seeds they contained and in part to the presence of an appreciable number of dead seeds, for empty seeds were no more numerous here than in younger cones.

Dead seeds were of no consequence in any of the other cone lots tested except in one from a 130-year-old tree in which they amounted to 7 percent.

The study also shows that jack pine produces viable seed to an age of almost 200 years and possibly longer. The number of viable seeds per cone, however, generally decreases with age. To some extent, this is paralleled by a reduction in the total number of seeds per cone and an increase in the proportion of empty seeds. This may be due to a combination of decreased fertility and smaller cone size. Some very old trees appear to produce sizable crops of cones of near-normal size. Others bear only a few small cones, and still others have numerous cones quite variable in size. The yield of seed by at least one overmature tree was directly related to cone size. The smallest cones also bore the highest proportion of empty seeds.

Jack pine seed from cones exposed to temperatures high enough to scorch them sometimes fail to germinate but at the same time appear to be viable. This suggests the possibility that high temperatures may sometimes induce dormancy in this normally nondormant seed.

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